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(54) LIQUID FILTERING APPARATUS

(71) We, BASS LIMITED, a British Company of High Street, Burton-on-Trent (formerly of 54 Baker Street, London, W1M 2AQ), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to liquid filtering apparatus, and particularly though not exclusively relates to apparatus of use in filtering beers.

In the production of keg beers, for example, the beer is sterilised before it is put into kegs. If any contaminating micro-organisms remain in or enter into the beer after sterilisation the beer may be spoilt or at least its acceptable storage life may be shortened. It is therefore desirable to monitor the beer for contamination after the sterilising process.

Conventionally the beer is monitored by taking samples, by one of two methods, and testing those samples. One method is to take individual samples from batches of beer at intervals of time, say at 1 or 2 hourly intervals, and to subject the samples subsequently to filtration under laboratory conditions. The other method is to divert continuously a small proportion of the beer after the sterilising process and to filter it at the site of sampling, the filtering process being continuous over a period of time, usually 2 or 3 hours, and then to inspect the filter. In both methods any micro-organisms present in the beer sampled are retained on the filters.

Neither method enables a precise indication to be obtained of the quantity of beer affected by any contamination because it cannot be ascertained by either method at which part of the period during which beer was sampled the contamination occurred.

The present invention seeks to provide filtering apparatus which can be used in monitoring a liquid such as beer and is more informative than the conventional methods of monitoring beer described above. The invention has primarily been developed in connection with the monitoring of beer but the invention may be of use in filtering other liquids as well, for example in filtering liquids for pharmacological purposes.

According to the present invention there is provided liquid filtering apparatus comprising a device including supply means operative over a period of time to supply liquid to be filtered to discharge means, the apparatus also including a filter in the form of a flexible strip for filtration of the liquid retention of micro-organisms present in the liquid, and a removable and replaceable unit for holding the filter strip, the unit comprising a body with storage means and take-up means for the filter strip, there being means operative in use to cause the filter strip to move progressively from the storage means to the take-up means by way of a filtration station, the arrangement being such that in use successive portions of liquid discharged by the discharge means are filtered at the filtration station by successive portions of the filter strip.

The supply means may be such as to cause an unbroken stream of liquid to be discharged by the discharge means, or it may be such as to cause liquid to be discharged intermittently, as for example in drops, at intervals very small compared with the period of time, so that the liquid passes substantially continuously to the filter. The liquid to be filtered may be withdrawn at least substantially continuously from the source of liquid to be monitored and filtered without delay. Alternatively a series of separate samples of the liquid may be prepared, each sample or a portion thereof then being filtered in turn. If desired a sterilizing fluid may be passed through the apparatus between successive filtrations.

It can be ascertained from the filter at what stage or stages any micro-organisms appear in the liquid during the period of time, and at what stage or stages during that period the liquid is free or substantially free of micro-organisms. To enable the actual times to be easily determined a time scale may be included in conjunction with the filter.

In a preferred method of using the apparatus the liquid is supplied at a controlled rate to the filter so that the concentration or at least the relative concentration of any micro-organisms in the liquid can be determined.

A band-like trace may be produced on the filter by the application of the liquid to the filter. It is to be understood that the trace is not necessarily visible and that, for example, if the liquid being filtered is both colourless and sterile, no visible trace is produced.

A preferred form of filter strip comprises a membrane filter having a defined pore size. The storage means for the filter strip preferably comprises a storage spool, preferably in a cassette, and the take-up means preferably comprises a driven take-up spool. As the liquid is applied to the strip a band-like trace is produced on the strip which extends along the length of the strip. If the take-up spool is driven at a constant angular velocity, and it is desired to ensure that throughout its length the strip is drawn at a substantially constant velocity past the point of application of the liquid, the take-up spool should be of a large radius compared with the total radial thickness of the strip when it is wound completely onto the take-up spool. It is desirable to arrange that an impermeable barrier is interposed between the layers of the strip wound onto the take-up spool to keep the layers separate and thereby to prevent any transfer of micro-organisms on the strip from one layer to another. The barrier may also serve to prevent or reduce the likelihood of adhesion between the layers of the filter strip when the strip is wound up.

Suction may be applied to the filter to assist filtration or increase the rate of filtration. The suction may be applied at a porous filter support into which the liquid drains after it has been passed through the filter.

Preferably a nutrient solution is applied to the filter means to keep alive any micro-organisms retained on the filter means from the filtration. It has been found most effective to apply the solution after filtration, rather than before the liquid is applied to the filter. Thus discharge means for emission of nutrient solution onto the filter may be positioned just beyond the discharge means for the liquid.

Delivery of the liquid to the filter at a carefully controlled rate is desirable as indicated above. A peristaltic pump may be used for this purpose. Such a pump is particularly suitable because it has the additional advantage of enabling the liquid to be conveyed to the filter means in a manner such that sterile conditions can be relatively easily maintained.

The supply of a nutrient solution to the filter is also preferably controlled by means of a peristaltic pump.

Preferably filtration is carried out with the filter and the unit sterilised beforehand, and it should be carried out in a sterile environment so as to minimise the risk of any contamination appearing on the filter other than that retained by filtration of the liquid. Filtration may be effected in a filtration chamber which contains the required sterile environment. The chamber may contain air which is rendered sterile by being passed through a suitable air filter, and is passed through the interior of the chamber. The air may be re-circulated, in which case it is passed through the air filter each time it is re-circulated so that the purity of the air is maintained. Preferably the interior of the chamber is maintained at super-atmospheric pressure so as to discourage ingress of contaminating matter from the atmosphere outside the chamber whenever the chamber is opened.

The filtration chamber may be contained in a cabinet or other housing, and the pumps mentioned above for delivering the liquid and nutrient solution to the filter may be provided in that cabinet or housing, together with receptacles for the filtrate and the nutrient solution.

It is possible that more than one source of liquid may be sampled at the same time with the aid of apparatus embodying the present invention. Thus there may be a plurality of supply means and a plurality of discharge means operative of produce a plurality of traces on the filter, one for each liquid, the traces being alongside one another and each trace being separate and distinct from the other trace or traces. When the filter strip is to carry two or more traces in this manner each trace is preferably separated from the next adjacent trace by a liquid-repellant band or strip incorporated in the filter strip and operative to prevent or at least reduce any tendency there might otherwise be for liquid from one trace to merge with that of the neighbouring trace or of a neighbouring trace. Where the liquid being filtered is water or water-based the liquid-repellant band or strip, each such band or strip, is hydrophobic.

The conventional manner of testing the residue retained on a filter after filtration for the presence of micro-organisms is to

add a nutrient to the residue which encourages the growth of any organisms in it to a size such that they can be readily seen and counted. This usually takes 48 hours or more. Thus there is a substantial delay between taking a sample from a liquid and finding out whether or not it is contaminated. This long delay may be acceptable in some instances but in others it may be highly unsatisfactory because a substantial amount of liquid may be contaminated to such an extent that it is spoilt and perhaps rendered completely unusable, before the contamination is detected and remedial action can be taken. Thus although the filter from apparatus embodying the present invention may be tested in the conventional manner, after it has been used in filtering a liquid, with a view to detecting the presence of micro-organisms, it is preferred to use a manner of testing which enables contaminating micro-organisms to be detected very much more quickly, possible even in a matter of minutes in some cases. This manner of testing is an adaptation of a technique which relies on enzymic hydrolysis of fluorescein diacetate by living micro-organisms. Free fluorescein is liberated as a result of esterase activity and accumulates within the organisms rendering them fluorescent when viewed under incident light.

Instead of being used to filter liquid supplied to the discharge means continuously, the apparatus may be used in the following manner: liquid is sampled periodically to provide a series of separate liquid samples. Each sample or a portion of each sample is in turn passed through the supply means to the discharge means so that each sample or portion of liquid is filtered through a different portion of the filter. If desired, between the filtration of each successive sample or portion a sterilizing solution is passed through the supply means and discharge means, and through any other parts of the apparatus which might become contaminated, so that the results of each filtration are not affected by those of the previous filtrations.

One form of apparatus embodying the invention will now be described, by way of example only, with reference to the accompanying drawings in which,

Figure 1 is a side view of a filter unit constituting part of the apparatus,

Figure 2 is a plan view of the filter unit,

Figure 3 is an end view of the filter unit as viewed from the left of Figure 1, but with the cassette and take-up spool removed,

Figure 4 shows the cassette spindle,

Figure 5 shows the cassette casing,

Figure 6 is a plan view of the filter support of the unit, to a larger scale,

Figure 7 is a section substantially along the line 7-7 of Figure 6, and

Figure 8 is a partly diagrammatic perspective view of a cabinet for receiving the filter unit shown in Figures 1 to 7, parts being omitted and broken away to reveal the interior.

The apparatus is intended for use in the monitoring of keg beer. The beer to be monitored is taken continuously over an extended period of time from a point on a pipe line through which beer is conveyed, after it has been sterilised, to a racking station where it is fed into kegs.

A self-sealing rubber diaphragm covers an opening in the wall of the pipe line, and a hollow needle is inserted through the diaphragm. Beer flows through the needle and a small bore delivery tube to a peristaltic pump 10 (Figure 8) which meters it at a closely controlled rate to a filter unit of the kind shown in Figures 1 to 7 of the accompanying drawings. The delivery tube is of small bore, for example of the order of 0.8 mm internal diameter, to ensure that the beer passes to the peristaltic pump 10 at a high velocity which discourages build up of contaminants in the tube on any occasions when the beer being sampled is contaminated. As peristaltic pumps are unable to operate at high pressures, immediately before the beer reaches the peristaltic pump 10 it passes through a Tee-piece which is fitted to the delivery tube and provides an expansion chamber which causes the velocity of the beer to be reduced and the pressure to be reduced to a level acceptable to the pump.

The filter unit comprises a body having two spaced parallel side plates 11 between which a cassette 12 and a take-up spool 13 are detachably mounted. The side plates 11 are of laterally elongated, generally triangular shape as best seen in Figure 1. The cassette 12 and take-up spool 13 are positioned near to the opposite ends of the bases of the triangular side plates.

The cassette 12 comprises a spool 14 shown in Figure 4, and a casing 15 shown in Figure 5. The spool 14 is mounted for rotation, while the casing 15, which is freely mounted on the spool does not in use rotate. The casing 15 has a slot 16 and one of its end plates 17 is removable to enable access to be had to the interior of the cassette. The spool 14 has projecting ends 18, of a bearing material, which slide into engagement with slots 19 in the side plates 11. The slots 19 have mouths at those inclined side edges of the side plates that are remote from the take-up spool 13. Latch bars 20 pivoted at their upper ends to the side plates above the slots 19 swing downward across the mouths of the slots to retain the ends 18 of the spool 14 in the slots. The latch bars 20 are secured in their spool-retaining positions be screws, not shown, which enter threaded holes in

the opposite ends of the latch bars and screw into tapped holes in the side plates below the slots 19.

The take-up spool 13 is of substantially larger diameter than the spool 14 of the cassette 12. A drive shaft 21 can be inserted through aligned bearings 22 in the side plates 11 and through an axial hole in the take-up spool 13. One end of that axial hole has a mouth of square cross-section which is entered by a portion 23 of the drive shaft of complementary square section so that rotation of the drive shaft causes rotation of the take-up spool. That end of the driving shaft 21 further from the squared portion 23 is so formed as to be engageable with the output shaft of an electric motor 24 (see Figure 8), the arrangement being such that when the driving shaft is inserted in the filter unit and the filter unit is mounted in the cabinet shown in Figure 8, in the manner described below the driving shaft automatically engages the output shaft of the motor so that operation of the motor causes rotation of the driving shaft and the take-up spool.

A roller 25 is mounted in slots 26 (Figure 1) at the apices of the side plates 1. Below the roller 25 two closely spaced, similar small bore supply tubes 27 and 28, for example of 2 mm bore diameter, pass at the same level horizontally through, and are fixed to, one of the side plates. The supply tubes 27 and 28 extend half way across the distance between the side plates, and their end portions are directed vertically downwards to form depending discharge heads 29 and 30 respectively. The supply tube 27 which is nearer to the cassette 12 is adapted to be connected outside the body of the filter unit to the peristaltic pump 10 mentioned above so as to receive beer metered by the pump. The other supply tube 28 is adapted to be connected outside the body to a second peristaltic pump 31 arranged to supply a preservative solution to that supply tube, as will be described below.

A filter support 32 is mounted below the two discharge heads 29 and 30, between the side plates. The filter support 32 is in the form of a block of plastics material, preferably p.t.f.e., having a series of vertically extending cylindrical perforations 33 in it as shown in Figures 6 and 7. Conveniently the perforations 33 have diameters of approximately 3 mm. The perforations 33 lead into a threaded socket 34 formed in the underside of the filter support 32 and an externally threaded drainage plug 35 is screwed into that socket. The drainage plug 35 has a flared entry 36 into which the perforations 33 discharge and which leads to an axial passage 37 in an integral spigot 38 depending from the plug. The plug is adapted to be connected by the spigot 38 to a suction pump 39 for producing a partial vacuum below the filter support.

A membrane filter 40 of strip form and an overlying imperforate barrier strip 41 of plastics material for example of p.t.f.e., are wound onto the spool in the cassette 12. The membrane filter 40 may be of the kind sold by Gelman & Hawksley Limited under the Registered Trade Mark "ACROPOR" which has a defined pore size, preferably of 0.45 microns. In a particular example the membrane filter 40 and barrier strip 41 are both 5 cms wide. The membrane filter 40 is drawn from the cassette 12, over the filter support 32 and its end is attached to the take-up spool 13. The two discharge heads 29 and 30 are disposed directly above the longitudinal centre line of the filter. The barrier strip 41 is drawn from the cassette, over the roller 25 above the filter support and discharge heads and is attached to the take-up spool so that it again overlies the membrane filter 40.

Near the bases of the side plate 1 there are two horizontally spaced, parallel mounting tubes 42 which extend between and are secured at their ends to the side plates.

In use filter unit is detachably fitted in a sterile cabinet of the kind shown in Figure 8. The interior of the cabinet is subdivided into a plurality of compartments or chambers each having a door or removable panel to enable access to be obtained to it. One of the compartments, 43, contains the peristaltic pumps 10 and 31 and containers 44 and 45. The container 44 contains the preservative solution metered to the discharge head 30 by the pump 31, while the container 45 is adapted to receive filtrate from the passage 37. Another compartment, 46, houses the suction pump 39, while another compartment, 47, houses the electric motor 24.

A filtration chamber 48 receives the filter unit and has a hinged door 49 at the front. The back of the chamber 48 is constituted by an air filter 50, such as that sold by Clean Room Construction Limited under the proprietary name "HEPA". The top panel 51 of the chamber 48 is of open-work construction and supports a fan 52. The arrangement is such that when the door 49 is closed and the fan 52 is operative, air is forced into the chamber 48 through the filter 50 and is withdrawn through the open-work top panel 51. The air is thus circulated and re-circulated with laminar flow, and the arrangement is such that the pressure in the chamber 48 is above atmospheric pressure so that if the chamber leaks there is no tendency for air to leak into the chamber.

In the chamber 48 there are supporting rods 53 which project horizontally forwards. The filter unit is supported in the chamber by means of the rods 53 which project through the mounting tubes 42. As the unit is positioned on the rods the shaft 7 of the

take-up spool automatically engages with the output shaft of the electric motor 24. When the unit is in place the supply tubes 27 and 28 are connected by means of flexible tubing (not shown) to their respective peristaltic pumps 10 and 31, and the spigot 38 of the drainage plug 35 is connected to the suction pump 39.

The filter unit, including the cassette 12 loaded with the membrane filter 40 and barrier strip 41, and including the take-up spool 13, is sterilised before it is placed in the cabinet. Conveniently it may be sterilised in an autoclave. Whilst the unit is in the cabinet it remains sterile due to the air filtration described above. It will be appreciated that the use of the cabinet enables the filter unit and associated apparatus to be operated under sterile conditions even though they may be used in industrial surroundings which are prone to contain contaminating matter. Thus the cabinet provides for use in ordinary industrial situations sterile conditions of a kind that would normally be found only in a laboratory. The cabinet is usually positioned close to the point at which beer to be filtered is drawn from the pipe line.

When the filter unit has been mounted in position in the filtration chamber 48 and all the necesary connections have been made, the beer withdrawn from the pipe line is filtered in the manner now to be described. The motor 24 which drives the take-up spool 13 is set into motion so that the membrane filter 40 is drawn at a slow, constant velocity, for example of the order of 10 cms/hour, across the filter support 32 below the two discharge heads 29 and 30 and on to the take-up spool 13, the barrier strip 41 being spaced by the roller 25 from the membrane filter 40 as the filter passes below the discharge heads. While the membrane filter 40 is moving past the heads the peristaltic pump 10 meters the beer to the discharge head 29 at a constant rate, for example 200 ml/hour. The beer drips from the discharge head onto the filter in a series of discrete drops and produces a substantially continuous band-like trace of the membrane filter extending lengthwise of the filter. The partial vacuum produced below the filter support 32 by the suction pump 39 encourages the filtrate to pass into the drainage plug 35 whence it passes to the container 45 in the cabinet. The pressure below the filter support is preferably about half atmospheric pressure.

Beyond the beer discharge head 29 the nutrient solution drips on to the membrane filter 40 from the second discharge head 30. The solution is taken from the container 44 and is metered to the discharge head 30 at a constant rate, for example at 30-50 ml/hour, by the peristaltic pump 31. The nutrient solution is an aqueous solution containing sucrose and a yeast nitrogen base, typically 20% sucrose and 0.5% yeast nitrogen base. Its purpose is to prevent death by desiccation of any micro-organisms retained on the membrane filter 40 from the filtration of the beer. If desired, alternative types of nutrient solutions may be used.

When the filter unit is used in the filtration of a beer having a high gas content, such as a lager beer, there is a tendency for the beer to form a foam on the membrane filter 40. The foam tends to be stable, and unless it is destroyed it interferes with the filtration process. To counteract the tendency for stable foam formation a wetting agent may be applied to the membrane filter. Conveniently the wetting agent may be mixed with the nutrient solution in the container 44. A suitable wetting agent is that sold under the Registered Trade Mark "TWEEN 80". The wetting agent may constitute about 0.2% of the solution.

As the membrane filter 40 is wound on to the take-up spool 13 the barrier strip 41 covers it and prevents any micro-organisms in the trace on the filter from being transferred from one part of the filter to another. The barrier strip also serves as a spacer to prevent adhesion between the layers of the filter.

Beer is supplied to the moving filter over whatever period of time is desired, the length of the filter being selected appropriately. The period may for example be up to 24 hours.

At the end of the period the filter unit is removed from the filtration chamber. It may immediately be replaced by another filter unit so that if required sampling can continue almost without interruption. The filter is removed from the cassette of the filter unit that has been withdrawn from the cabinet and is tested for the presence of micro-organisms in the trace. When the filter with its barrier strip has been removed from the cassette, the cassette may be re-loaded with another membrane filter and barrier strip, or another loaded cassette may be fitted to the unit, and the unit can then be sterilised in readiness for further use.

For the rapid detection of contaminatig micro-organisms, generally yeast cells, on the membrane filter, the filter is treated in the manner mentioned earlier in this specification which renders the organisms fluorescent. Further, the filter may be treated with 0.5% w.v. sodium acetate solution, which may be incorporated in the nutrient solution, to induce optimum esterase activity. This enables an especially reliable estimate of contamination to be made since many strains of yeast isolated from brewery sources fail to fluoresce, or fluoresce poorly if exposed directly to fluorescein diacetate

without prior enhancement of esterase activity.

In one particular method the filter is treated, under laboratory conditions, with 0.01% w.v. fluorescein diacetate in a phosphate buffer of pH 7.2, usually for about 15 minutes. Next the filter is washed with phosphate buffer of pH 7.2 and counterstained with Rhodamine B at 0.125% w.v. in a citrate buffer of pH 7.6. The Rhodamine B has three functions. Firstly, it masks the autofluorescence exhibited by some strains of yeast in the absence of fluorescein diacetate. Autofluorescence is usually of very low intensity but unless it is eliminated it can lead to some uncertainty when interpreting the results. Secondly, Rhodamine B stains much of the protein and other debris associated with beers and thus facilitates rapid scanning. Thirdly, by staining dead cells pink/brown it can provide a method for estimating the percentage viability of yeast samples.

After having been stained with Rhodamine B the filter is washed again with phosphate buffer, cut into lengths and mounted on a glass slide for visual examination under incident blue illumination. Any viable yeast cells and bacteria can be identified by their fluorescence.

The presence and extent of any contamination can be readily ascertained by visual inspection of the filter. The position of fluorescence on the filter shows at what time contamination began during the period that beer was sampled and for how long the contamination was present in the beer. This enables the quantity of beer affected to be determined. Further, because a clear record is presented by the filter of the state of the beer at any particular time during which sampling was carried out, the filter can be of considerable assistance in enabling the cause of the contamination to be determined so that remedial action may be taken. Thus, if contamintion is revealed on the filter, the time at which the contamination occurred can be determined, and an enquiry can then be made to see whether anything likely to cause contamination occurred at that time in the course of supplying the beer to the pipe line from which the sample was taken.

Filtration and the subsequent treatment of the filter to render fluorescent, for rapid detection, any contaminating micro-organisms retained on the filter may be combined together into an automatic process. Thus whilst filtration is taking place through parts of the filter the trace produced on parts of the filter already used in the filtration may be subjected to the treatment that renders micro-organisms fluorescent. Scanning means may be provided which automatically scans the treated trace for micro-organisms rendered fluorescent. The scanning means may be linked to an alarm or other signalling means which is operated when any mirco-organism or more than a predetermined minimum concentration of micro-organisms is detected in the trace, and/or the scanning means may be arranged to bring about a halt at an appropriate stage in the production of the beer or other liquid being monitored.

WHAT WE CLAIM IS:

1. Liquid filtering apparatus comprising a device including supply means operative over a period of time to supply liquid to be filtered to discharge means, the apparatus also including a filter in the form of a flexible strip for filtration of the liquid and retention of micro-organisms present in the liquid, and a removable and replaceable unit for holding the filter strip, the unit comprising a body with storage means and take-up means for the filter strip, there being means operative in use to cause the filter strip to move progressively from the storage means to the take-up means by way of a filtration station, the arrangement being such that in use successive portions of liquid discharged by the discharge means are filtered at the filtration station by successive portions of the filter strip.

2. Apparatus according to Claim 1 in which the discharge means comprises a discharge head constituting part of the unit and releasably connectable to the supply means.

3. Apparatus according to either of Claims 1 and 2 in which the supply means comprises a peristaltic pump.

4. Apparatus according to any of the preceding Claims in which the filter strip comprises a filter membrane of defined pore size for retaining micro-organisms.

5. Apparatus according to any of the preceding Claims in which the take-up means comprises a rotatable spool and the drive means constitutes part of the device and is operatively coupled to the take-up spool when the unit is mounted on the device.

6. Apparatus according to any of the preceding claims in which there is porous filter support at the filtration station, through which liquid can be drained after it has passed through the filter.

7. Apparatus according to Claim 6 in which the filter support constitutes part of the unit.

8. Apparatus according to either of Claims 6 and 7 in which the device includes suction means operative to reduce pressure beneath the filter support so as to assist the passage of liquid through the filter.

9. Apparatus according to any of the preceding Claims in which there is a flexible barrier strip interleaved with the filter strip.

10. Apparatus according to Claim 9 in which the unit includes storage means and take-up means to enable the filter strip to follow a first path and the barrier strip to follow a second path, spaced from the first path, the arrangement being such that the barrier strip is separated from the filter strip in the neighbourhood of the filtration station.

11. Apparatus according to any of the preceding Claims in which the device includes a filtration chamber for receiving the unit, means for circulating air through the filtration chamber and means for rendering sterile the air to be circulated through the chamber.

12. Apparatus according to any of the preceding Claims in which there is nutrient supply means operative to supply nutrient liquid, for maintaining the viability of filtered micro-organisms, to nutrient discharge means, the arrangement being such that in use nutrient liquid is discharged by the nutrient discharge means onto successive portions of the filter strip.

13. Apparatus according to Claim 12 in which the nutrient discharge means comprises a nutrient discharge head constituting part of the unit and releasably connectable to the nutrient supply means.

14. Liquid filtering apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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1571480 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

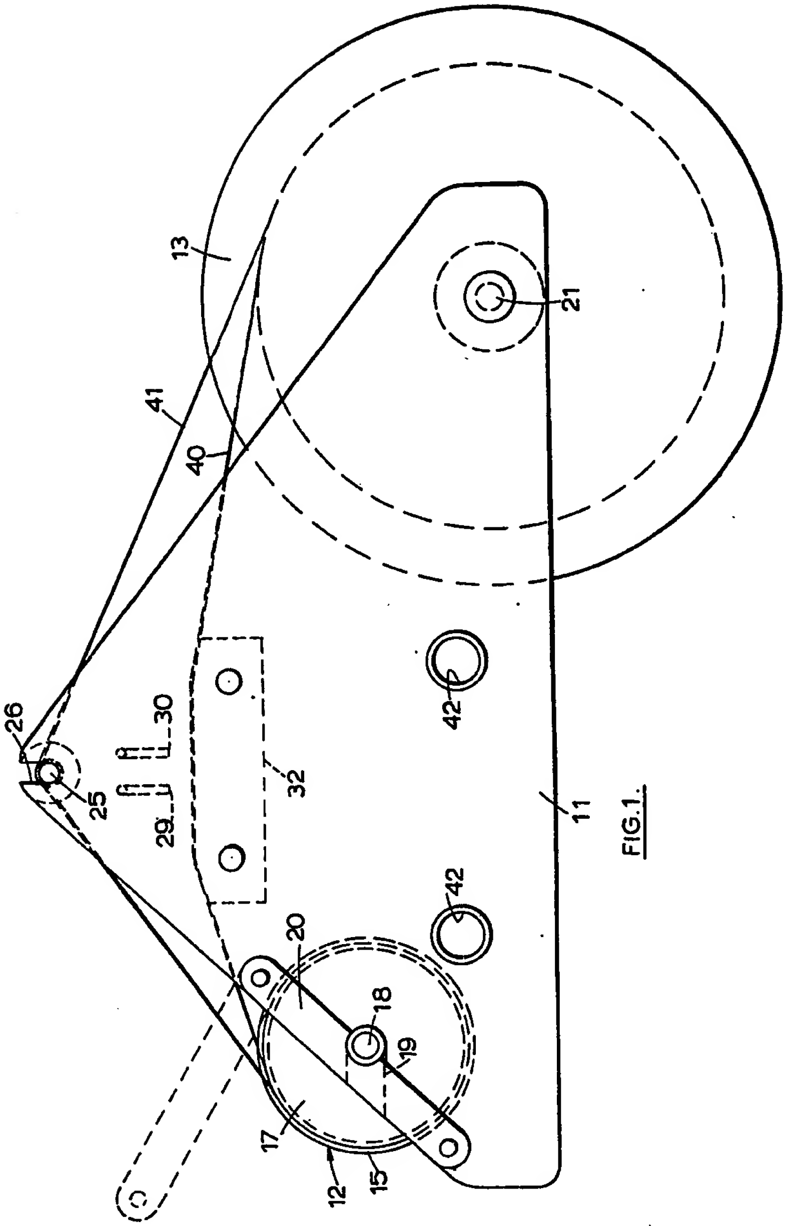

FIG.1.

1571480 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

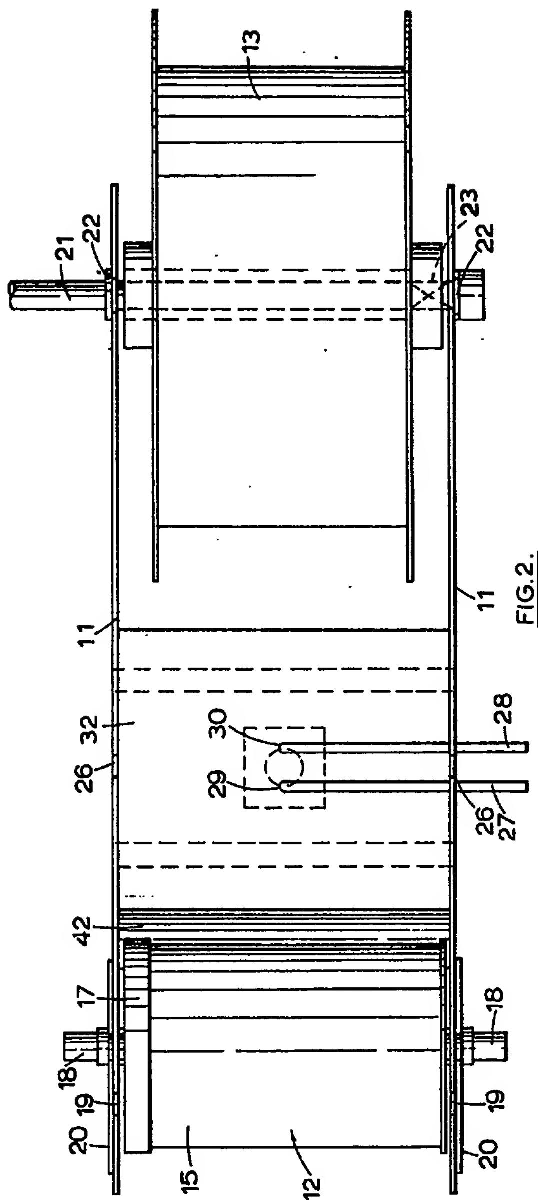

FIG.2.

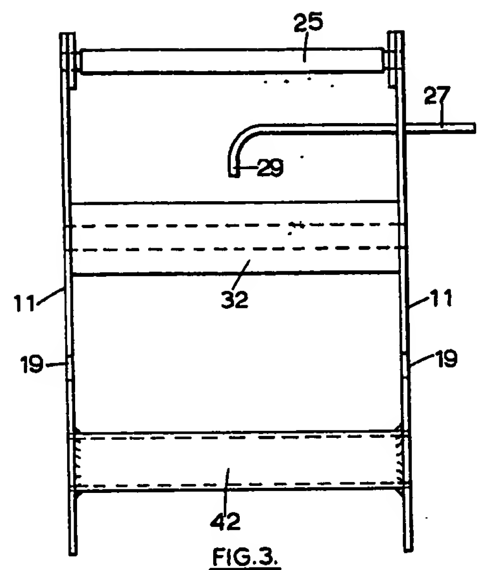

FIG.3.

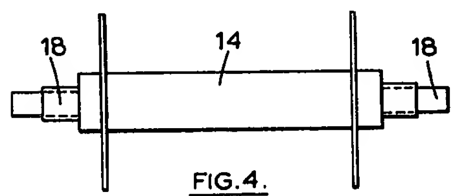

FIG.4.

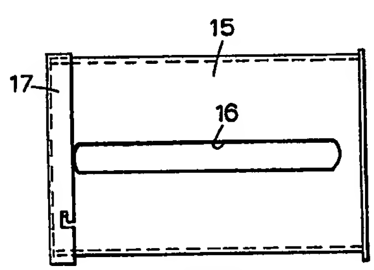

FIG.5.

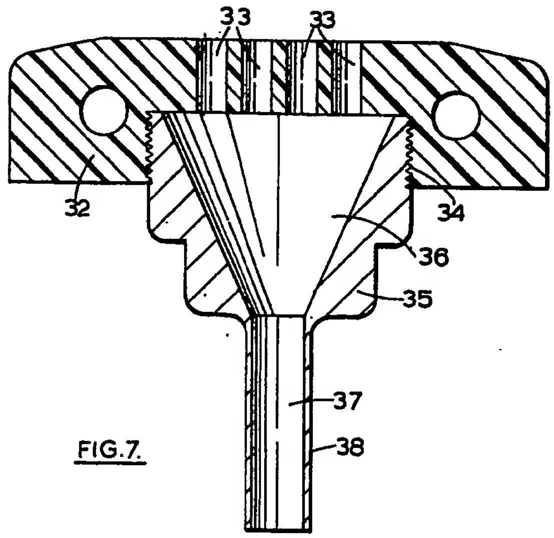

FIG.7.

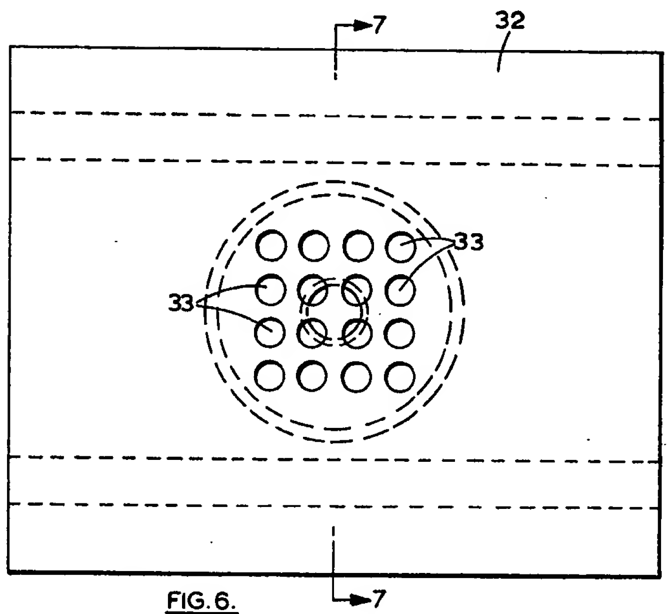

FIG.6.

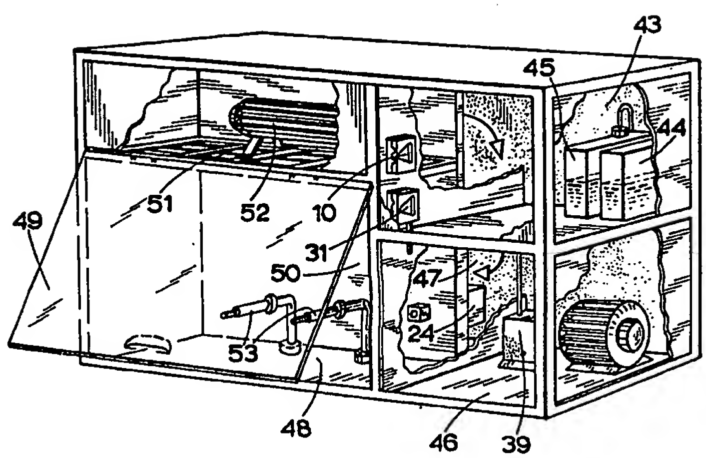

FIG.8.